

# A High Accuracy Measurement Circuit for Soil Moisture Detection

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**Abstract**—The study of soil for agriculture purposes has remained the main focus of research since the beginning of civilization as humans' food related requirements remained closely linked with the soil. The study of soil has generated an interest among the researchers for very similar other reasons including transmission, reflection and refraction of signals for deploying wireless underground sensor networks or for the monitoring of objects on (or in ) soil in the form of better understanding of soil electromagnetic characteristics properties. The moisture content has been very instrumental in such studies as it decides on the resistance of the soil, and hence the attenuation on signals traveling through soil or the attenuation the signals may suffer upon their impact on soil. This work is related testing and characterizing a measurement circuit meant for the detection of moisture level content in soil.

**Keywords**—Analog–digital Conversion, Bridge Circuits, Intelligent sensors, Pulse Time Modulation, Relaxation Oscillator.

## I. INTRODUCTION

THE increasing use of microprocessors and microcontrollers in measurement and data acquisition systems has enhanced the need for obtaining the transducer response in a form suitable for conversion to a digital format, obviously using suitable signal measurement and conditioning circuits. From this view point, it is desirable to obtain signals which are proportional representative of the changes in the parameter of interests. In resistive in resistive transducers changes in resistances are proportional to parameters that can be easily used for a useful applications in the industry. A simple resistance-to-frequency converter of high resolution has been recently reported, which uses a bridge amplifier, an integrator and a comparator as building blocks. In this project, it is shown that using the same building blocks connected in a different fashion, it is possible to obtain a time-period output linearly varying with changes in resistance. An analysis of the proposed circuit, discussed in the following sections, brings out its features and advantages over other related schemes.

The study of soil for agriculture purposes has remained the main focus of research since very long, however in recent works soil has been under the attention of researchers for reasons including transmission, reflection and refraction of signals for deploying wireless underground sensors network or for the monitoring of objects on soil in the form of better

understanding of soil electromagnetic characteristics properties [1-3]. The moisture content has been very instrumental in such studies as it decides on the resistance of soil, and hence the attenuation on signals traveling through soil or the attenuation signals may suffer during their impact on soil.

Measurement circuits are making fundamental components in both resistive and capacitive transducers designed and installed for monitoring parameters of interests [4-6], and such circuits have been reported recently with renewed content materials. However, limited range and resolution are the main topics which have been attracting interest among the researchers for deployment with sensitive applications [7-8].

In this paper a high accuracy measurement circuit, employing a bridge amplifier, an integrator, and a comparator, for detecting the moisture content of soil is suggested. This circuit has the advantage of detecting soil resistance with better accuracy and with wide-range linearity when compared with other similar works. The results shows a good level of linearity as it has been tested for voltages proportional to changes in resistances are very closely related with the measured values of voltages due to variations in a resistor from 950  $\Omega$  to 2550  $\Omega$ , and the results show a very much linear behavior.

The circuit used in this work is for detecting soil moisture content which is emulated as a variable resistor resulting into an RC circuit being charged up to a voltage level enough to turn the indicating LED ON. The features of the circuit are described in the experimental setup section, along with the discussions on the circuit in the discussion and analysis section.

## II. EXPERIMENTAL SETUP

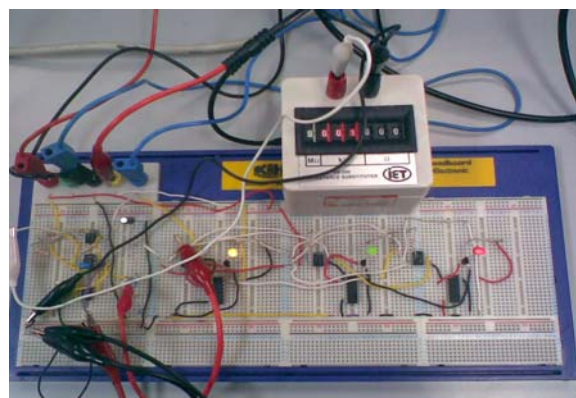


Fig. 1 Experimental Setup

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The experimental setup of Fig. 1 is in fact an implementation of the schematic shown in Fig. 2. The whole circuit is divided into three well distinct blocks – measurement Circuit, RC delaying circuit and control circuit.

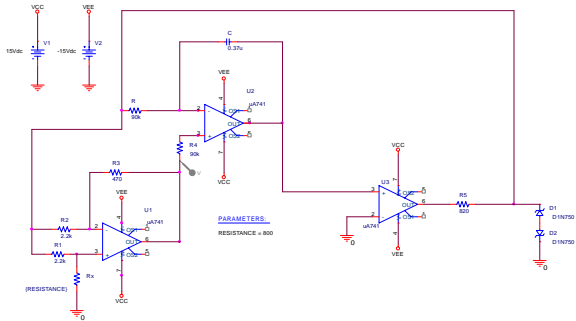


Fig. 2 Basic Circuit Converting Resistance Changes into Time-Period Changes

The measurement portion (Fig. 2) translates changes in resistances in to changes in time period of the resulting square wave, while the control units (Fig. 3) functions to charge the RC capacitor up to a proportionate level of voltage, which in turn is realized by the control circuit to accordingly turn the LEDs ON/OFF for the required indication of soil moisture content. The components values are chosen so that the voltage level is reached through a fully charged capacitor in the HIGH part of the square wave, and which in turn is not able to discharge in the LOW part of the square wave.

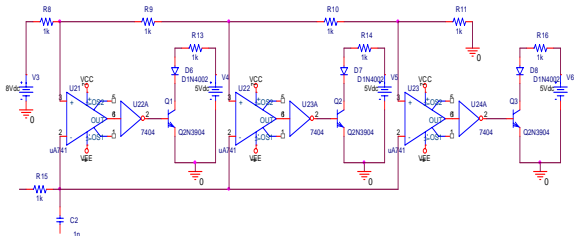


Fig. 3 Circuit Controlling Indication of LEDs

The circuit also possesses a high order of resolution and linearity as the resistance-to-frequency converter. These features, along with the absence of the need for providing a compensation arrangement and facility of having a grounded sensor, should favor the application of the proposed circuit for signal-conditioning of resistive transducers. The first OP-AMP of Fig. 2 outputs the voltage value with different  $R_x$  values, while the second OP-AMP is a differential amplifier. This differentiates the output waveform coming from OP-AMP1. The third OP-AMP outputs the differentiated waveform.

The circuit functions as a square wave oscillator when the bridge is unbalanced, with voltage at node,  $V_a$  and output voltage,  $V_0$  having the same polarity.

### III. EXPERIMENTAL RESULTS

The waveforms of comparator input,  $V_C$  and output,  $V_0$  are as shown in Fig. 4 (a-f).

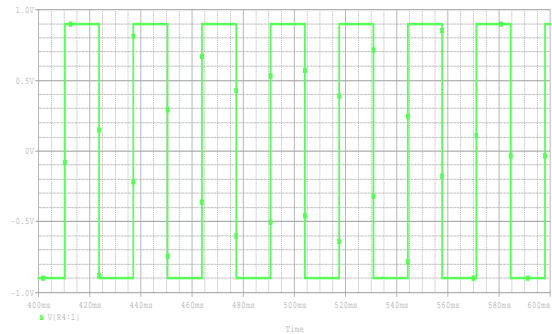


Fig. 4 (a) For  $R_x = 1k\Omega$ , the output waveform of OP-AMP1

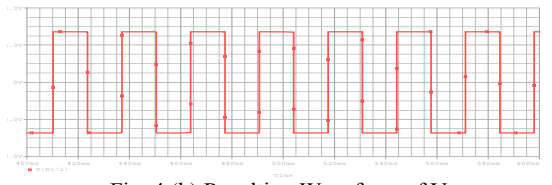


Fig. 4 (b) Resulting Waveform of  $V_0$

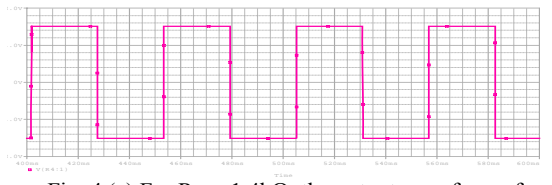


Fig. 4 (c) For  $R_x = 1.4k\Omega$ , the output waveform of OP-AMP1

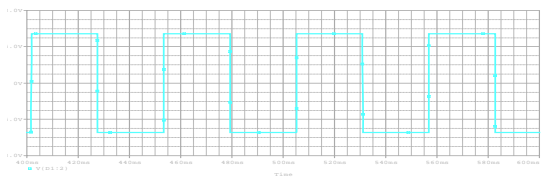


Fig. 4 (d) Resulting Waveform of  $V_0$

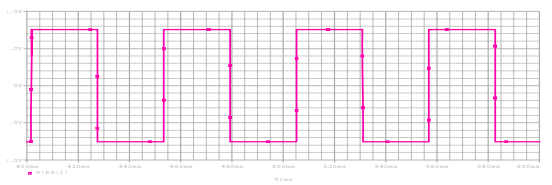


Fig. 4 (e) For  $R_x = 2k\Omega$ , the output waveform of OP-AMP1

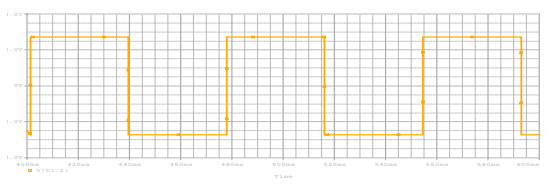


Fig. 4(f) Resulting Waveform of  $V_0$

As you can see from the output waveforms, changes in time-period lead to proportional changes in  $R_x$ .

#### IV. ISSUES OF LINEARITY AND SENSITIVITY

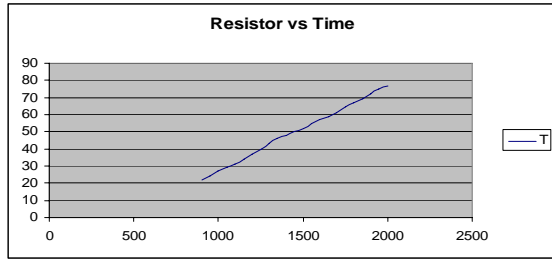


Fig. 5(a) Experimental Results Showing a Linear Response of the Circuit

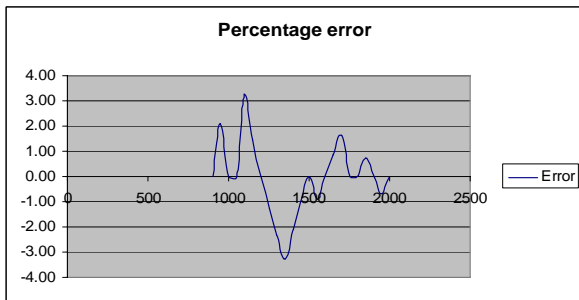
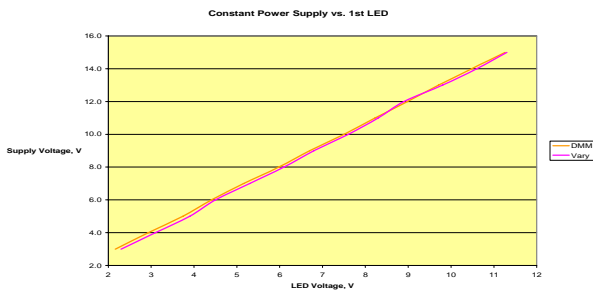
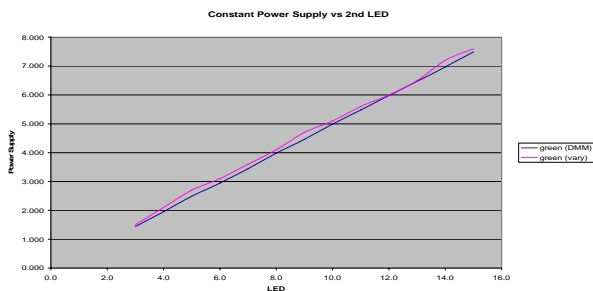


Fig. 5(b) Errors in Experimental Results with an Ideal Linear Response of the Circuit

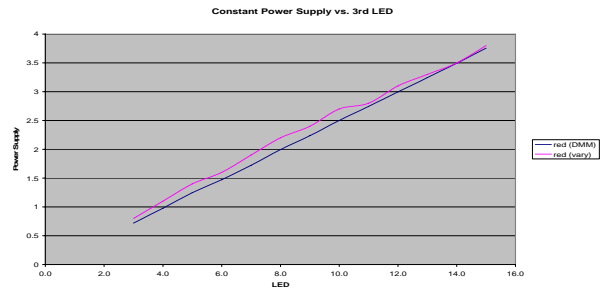
The measurement circuit shows up a good linearity (Fig. 5 a-b) as  $R_x$  is increased from  $900\Omega$  to  $2000\Omega$  in a step of  $50\Omega$ . This graph also verifies a direct proportionality between  $R_x$  and the time period of  $V_0$ .



(a)



(b)



(c)

Fig. 6 The voltages across the three LEDs for varying  $R_x$  values

The power supply to the LED circuit is tested to see the effect of changing the supply voltage, which shows that as the supply voltage is increased, the voltage level at which the LED's lit up was also increased. The same was repeated with the changes in  $R_x$ , and it was shown to be very much in linearity with the power supply variations. The voltages across the three LEDs for varying  $R_x$  values, is shown through Fig. 6 (a-c), which justifies the linearity behavior of the suggested measurement circuit. The values in the table confirm that the relationship between the value of the capacitance and the time period is linear. As the capacitance value increased, the time period also increased at certain amount.

The measurement circuit is further used as a soil moisture detector. As we know, the moisture in the soil could serve as an element that could add to the conductivity of soil. The higher the conductivity, the less the resistance of soil in a container, that is used to replace  $R_x$  of soil. The procedure used in this work is to show through turning ON an LED for a value of resistance over a certain range of resistance, for example, turning one LED ON for one level of moisture content, two LED's should light for a higher level, and three LEDs up for the highest level of moisture content. The output waveform agrees (if not completely) with the one shown for the value of  $R_x$ . Hence, we can conclude that our project can be applied to the usage of a soil moisture detector.

#### V. CONCLUSION

The results are obtained by the proposed measuring circuit with soil moisture contents have been presented, which demonstrate that the voltage across the RC circuit is proportional to variations in the soil resistance (or moisture content). A comparison between measured values and the voltage values as a result of the measuring circuit shows a good level of linearity. The results achieved are varying as the value of  $V_0$  varies directly with increased values of the time period of the square wave, as different values of  $R_x$  led to proportionately increased values of voltage across the capacitor, hence leading to lighting up the LEDs at different timings. The different values of moisture content will lead to different values of soil resistance, and hence accordingly varying values of voltages across the RC circuit. Their conductance/resistance will be measured by putting the probes/wires into the samples and the output voltage will be

observed using the oscilloscope. We are also plan to measure the conductivity value of certain soil. For example, we use only one particular soil sample, and by adding little by little water to measure its conductance value at certain level of moisture.

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